

WHAT IS CLAIMED IS:

1                   1.       A substrate processing chamber comprising:  
2                   a chamber body;  
3                   a chamber top disposed on the chamber body; and  
4                   a transformer-coupled plasma generator plate within the substrate  
5 processing chamber having a plurality of transformer cores within the transformer-  
6 coupled plasma generator plate and a plurality of through holes forming conduits from  
7 a first side of the transformer-coupled plasma generator plate to a second side of the  
8 transformer-coupled plasma generator plate, a first conduit passing through a first  
9 transformer core.

1                   2.       The substrate processing chamber of claim 1 further comprising  
2 a second conduit not passing through a transformer core.

1                   3.       The substrate processing chamber of claim 1 wherein the plasma  
2 generator plate is flat.

1                   4.       The substrate processing chamber of claim 1 further comprising  
2 a second transformer core within the transformer-coupled plasma generating plate, a  
3 first primary coil being disposed to electro-magnetically couple to the first transformer  
4 core and a second primary coil being disposed to electro-magnetically couple to the  
5 second transformer core, wherein the first primary coil and the second primary coil are  
6 connected to each other in series.

1                   5.       The substrate processing chamber of claim 1 wherein the toroidal  
2 transformer core comprises ferrite material.

1                   6.       The substrate processing chamber of claim 1 wherein the  
2 transformer-coupled plasma generator plate includes a dielectric spacer between the  
3 first side and the second side, and a remainder of an outer surface of the generator plate  
4 comprises an electrical conductor.

1                   7.       The substrate processing chamber of claim 6 wherein the  
2 dielectric spacer is disposed within a conduit through the transformer-coupled generator  
3 plate.

8. The substrate processing chamber of claim 1 further comprising an alternating-current power supply configured to operate at a frequency of about 1 KHz-2 MHz.

9. A substrate processing chamber comprising:  
a chamber body;  
a chamber top disposed on the chamber body;  
an alternating-current power supply; and  
a transformer-coupled plasma generator plate having a plurality of through holes forming conduits from a first side of the transformer-coupled plasma generator plate within the substrate processing chamber to a second side of the transformer-coupled plasma generator plate within the substrate processing chamber, a first portion of the conduits passing through centers of a plurality of toroidal transformer cores within the generator plate and a second portion of the conduits not passing through centers of transformer cores, the generator having a first surface comprising metal, a second surface comprising metal, and a plurality of dielectric spacers disposed between the first surface and the second surface in each of the first portion of the conduits.

10. A plasma generator plate comprising:  
a first side;  
a second side;  
a first conduit passing from the first side to the second side through a first transformer core within the plasma generator plate;  
a second conduit passing from the first side to the second side through a second transformer core.

11. The plasma generator plate of claim 10 further comprising a first dielectric spacer in a first secondary current path around the first transformer core.

12. A method of processing a substrate in a plasma processing system, the method comprising:  
providing a substrate to a substrate holder in a processing chamber of the plasma processing system;

5                   flowing a plasma precursor into a multi-core transformer-coupled  
6 plasma generator;  
7                   generating a plasma from the plasma precursor with the multi-core  
8 transformer coupled plasma generator; and  
9                   processing the substrate.

1                   13.     The method of claim 12 wherein the multi-core transformer-  
2 coupled plasma generator is within the processing chamber.

1                   14.     The method of claim 13 wherein the multi-core transformer-  
2 coupled plasma generator is a generator plate comprising a plurality of transformer  
3 cores within the generator plate and a plurality of through-holes forming conduits from  
4 a first side of the generator plate to a second side of the generator plate.

1                   15.     The method of claim 12 wherein plasma formed by the multi-  
2 core transformer-coupled plasma generator is coupled to the processing chamber  
3 through a conduit.

1                   16.     The method of claim 15 wherein the multi-core transformer-  
2 coupled plasma generator has a first conduit passing through a first transformer core  
3 and through a second transformer core.

1                   17.     The method of claim 15 wherein the multi-core transformer-  
2 coupled plasma generator has a first conduit passing through a first transformer core  
3 and a second conduit passing through a second transformer core.

1                   18.     A plasma processing system comprising:  
2                   a first substrate support structure configured to hold a first substrate in a  
3 processing chamber;  
4                   a second substrate support structure configured to hold a second  
5 substrate in the processing chamber; and  
6                   a transformer-coupled plasma generator within the processing chamber  
7 disposed between the first substrate support structure and the second substrate support  
8 structure.

1                   19.     The plasma processing system of claim 18 wherein the  
2 transformer-coupled plasma generator includes a toroidal transformer core.

1                   20.     The plasma processing system of claim 18 wherein the plasma  
2 generator comprises a plasma generating plate having a plurality of transformer cores  
3 within the plasma generating plate and a plurality of through holes forming conduits  
4 from a first side of the plate to a second side of the plate.

1                   21.     A method of simultaneously processing substrates in a plasma  
2 processing system, the method comprising:  
3                   providing a first wafer and a second wafer to a processing chamber;  
4                   flowing plasma precursor into the chamber;  
5                   generating a plasma with a transformer-coupled plasma generator  
6 disposed between the first wafer and the second wafer; and  
7                   simultaneously processing the first wafer and the second wafer.

1                   22.     A plasma generator comprising:  
2 an inlet in fluid communication with;  
3 a first conduit passing through  
4                   a first toroidal transformer core and through  
5                   a second toroidal transformer core;  
6                   a second conduit completing a plasma current circuit, in cooperation  
7 with the first conduit, around the first toroidal transformer core and around the second  
8 toroidal transformer core; and  
9                   an outlet in fluid communication with the first conduit.

1                   23.     A plasma generator comprising:  
2 an inlet in fluid communication with  
3 a first conduit passing through a first transformer core and with  
4 a second conduit passing through a second transformer core;  
5                   a third conduit in fluid communication with the first conduit to complete  
6 a first plasma current circuit around the first transformer and in fluid communication  
7 with the second conduit to complete a second plasma current circuit around the second  
8 transformer; and

9 an outlet in fluid communication with at least the first conduit and the  
10 second conduit.

1 24. A substrate processing system comprising:  
2 a process chamber with a chamber inlet;  
3 a chamber exhaust; and  
4 a transformer-coupled plasma generator having a first core,  
5 a first conduit passing through the first core,  
6 a second core,  
7 a second conduit passing through the second core, and  
8 a third conduit in fluid communication with the first conduit and  
9 the second conduit to complete a plasma current circuit path through the process  
10 chamber.

1 25. The substrate processing system of claim 24 wherein the third  
2 conduit is a center conduit completing a first plasma current circuit path around the first  
3 core through the process chamber and the first conduit and completing a second plasma  
4 current circuit path around the second core through the process chamber and the second  
5 conduit.

1 26. The substrate processing system of claim 24 wherein the first  
2 conduit and the second conduit comprise metal and further comprising a dielectric  
3 spacer in the plasma current circuit path.

1 27. The substrate processing system of claim 24 further comprising:  
2 a fourth conduit passing through  
3 a third core; and  
4 a fifth conduit passing through  
5 a fourth core.

1 28. The substrate processing system of claim 24 further comprising:  
2 a first primary coil disposed to couple electro-magnetic energy to the  
3 first core;  
4 a second primary coil disposed to couple electro-magnetic energy to the  
5 second core;

6 a third primary coil disposed to couple electro-magnetic energy to the  
7 third core;

8 a fourth primary coil disposed to couple electro-magnetic energy to the  
9 fourth core, wherein the first primary coil, the second primary coil, the third primary  
10 coil, and the forth primary coil are coupled to an AC power supply.

1 29. The substrate processing system of claim 28 wherein the first  
2 primary coil, the second primary coil, the third primary coil, and the fourth primary coil  
3 are connected in series with the AC power supply.

1 30. The substrate processing system of claim 28 wherein the first  
2 primary coil, the second primary coil, the third primary coil, and the fourth primary coil  
3 are connected in parallel to the AC power supply.

1 31. A plasma generator comprising:  
2 an inlet configured to receive a plasma precursor, the inlet in fluid  
3 communication with a first plasma current path and with a second plasma current path;  
4 a first conduit passing through  
5 a first transformer core;  
6 a second conduit passing through  
7 a second transformer core, wherein the first conduit is essentially co-  
8 linear with the second conduit.

1 32. A plasma generator comprising:  
2 an outer shell surrounding a first inner shell housing a first toroidal  
3 transformer core; and  
4 a second inner shell housing a second toroidal transformer core, wherein  
5 the first toroidal transformer core and the second toroidal transformer core are disposed  
6 along a common center axis.

1 33. The plasma generator of claim 32 wherein the first inner shell is  
2 supported within the outer shell by a web allowing circulation of secondary plasma  
3 current around the first inner shell within the outer shell.

1                   34.     The plasma generator of claim 33 wherein the web contains an  
2     electrical lead connected to a primary coil disposed to couple electro-magnetic energy  
3     to the first toroidal transformer core.

1                   35.     The plasma generator of claim 32 wherein the first inner shell  
2     includes a shaped bottom portion to provide a circular cross-section to the inner shell.

1                   36.     The plasma generator of claim 32 further comprising:  
2                   an inlet; and  
3                   an outlet, both the inlet and the outlet lying along the common center  
4     axis.

1                   37.     An ion implantation system comprising:  
2                   an ion source having a toroidal plasma generator, and  
3                   an ion source aperture aligned essentially along a center line of the  
4     toroidal plasma generator.

1                   38.     The ion implantation system of claim 37 further comprising a  
2     first extraction electrode disposed to accelerate ions from the ion source toward a  
3     second extraction electrode.

1                   39.     The ion implantation system of claim 37 wherein the toroidal  
2     plasma generator includes a first core and a second core, the first core and the second  
3     core being aligned essentially along a center line of the toroidal plasma generator.

1                   40.     A method of providing ions to an ion implantation system, the  
2     method comprising:  
3                   providing an ion precursor to a transformer-coupled toroidal plasma  
4     generator in an ion source;  
5                   ionizing at least a portion of the ion precursor into ions, the ions having  
6     a greater density at a center of the transformer-coupled toroidal plasma generator and  
7     extending along a line through the center of the transformer-coupled toroidal plasma  
8     generator; and  
9                   ejecting a portion of the ions out of the ion source.

1           41.     A plasma torch head comprising:  
2           an outer nozzle;  
3           an inner nozzle, the inner nozzle including a conduit passing through the  
4 inner nozzle from an inlet side toward an outlet,  
5           a toroidal transformer core surrounding the conduit; and  
6           a bypass providing a return path for a secondary plasma current circuit  
7 around the toroidal transformer core.

1           42.     The plasma torch head of claim 41 wherein the inner nozzle  
2 comprises metal and further including a dielectric spacer in the inner nozzle to prevent  
3 an electric path through the inner nozzle around the toroidal transformer core.

1           43.     The plasma torch head of claim 41 wherein a first gas is flown  
2 through the conduit and a second gas is flown through the bypass, the first gas being  
3 different from the second gas.

1           44.     The plasma torch head of claim 43 wherein the first gas is  
2 oxygen and the second gas is either propane or hydrogen.

1           45.     The plasma torch head of claim 41 further comprising a primary  
2 coil disposed to couple electro-magnetic energy to the toroidal transformer core  
3 wherein the primary coil and the toroidal transformer core are enclosed within the inner  
4 nozzle.

1           46.     A method of cutting material using a plasma torch, the method  
2 comprising:  
3           flowing a plasma precursor in a conduit through a center of a toroidal  
4 transformer core of a plasma generator in an inner nozzle of a plasma torch;  
5           forming plasma from the plasma precursor;  
6           completing a plasma current secondary circuit around the toroidal  
7 transformer core through a bypass; and  
8           transporting plasma out an outlet of the plasma torch.

1           47.     The method of claim 46 further comprising flowing carrier gas  
2 through the bypass.



1                   48.     The method of claim 46 wherein the forming plasma step  
2 includes providing a primary voltage to a primary coil coupling electro-magnetic  
3 energy to the toroidal transformer core, the primary voltage being an alternating-current  
4 voltage less than about 115 Volts.

1                   49.     An ion source for an ion milling apparatus, the ion source  
2 comprising:  
3                   a transformer-coupled toroidal plasma generator (having a primary coil  
4 disposed to couple electro-magnetic energy to a toroidal core, the transformer-coupled  
5 toroidal plasma generator disposed to provide plasma along a center line of the  
6 transformer-coupled toroidal plasma generator toward an accelerator plate.

1                   50.     The ion source of claim 1 wherein the transformer-coupled  
2 toroidal plasma generator further includes a second toroidal core.

1                   51.     A method for providing ions to an ion milling apparatus, the  
2 method comprising:  
3                   providing an ion precursor to a transformer-coupled toroidal plasma  
4 generator;  
5                   ionizing at least a portion of the ion precursor to form ions, the ions  
6 being concentrated along a center axis of the transformer-coupled toroidal plasma  
7 generator; and  
8                   ejection a portion of the ions toward an accelerator plate.

1                   52.     The method of claim 51 wherein the ion precursor forms reactive  
2 ions.